# How Will NSLS-II Serve Infrared Science?

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*NSLS Infrared*

and the NSLS-II design team

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BROOKHAVEN NATIONAL LABORATORY

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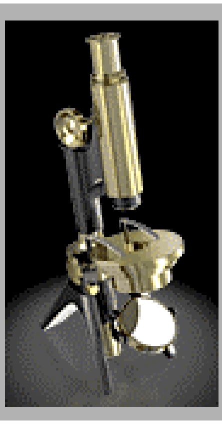
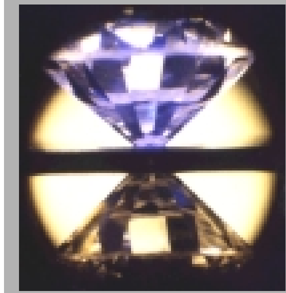
# Synchrotron Infrared Source Qualities

- High brightness
  - ~ 3 orders of magnitude higher than conventional “white” IR spectroscopy sources.
  - Needed for throughput limited spectroscopy (microspectroscopy)
- Broad spectral coverage
  - everything from visible down to microwaves, though weaker at long wavelengths.
  - Compatible with high-performance FTIR spectrometry.
- Pulsed output
  - 10s of picoseconds out to nanoseconds
  - Time-resolved spectroscopy / dynamics

# High Brightness Enables Throughput Limited Techniques



Microscopy at diffraction-limit

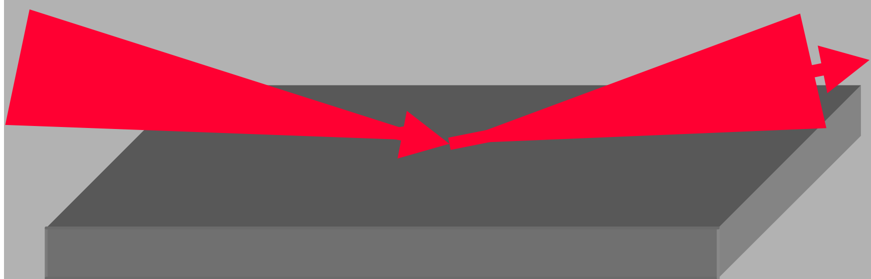


Spectroscopy of materials under extreme conditions:

- *diamond anvil cells*
- *complex cryostats & magnets*

Restrictive angle of incidence

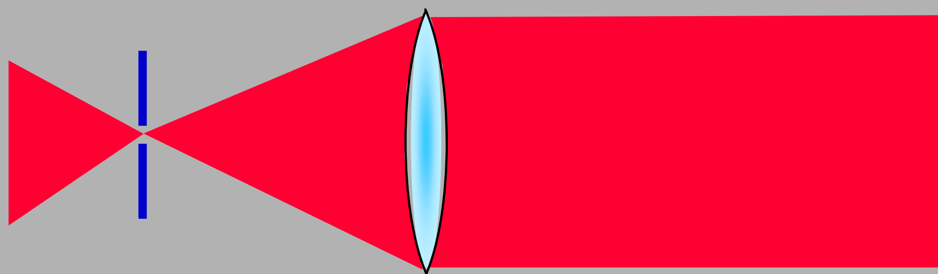
- Grazing incidence
- Attenuated total refl. (ATR)
- Ellipsometry



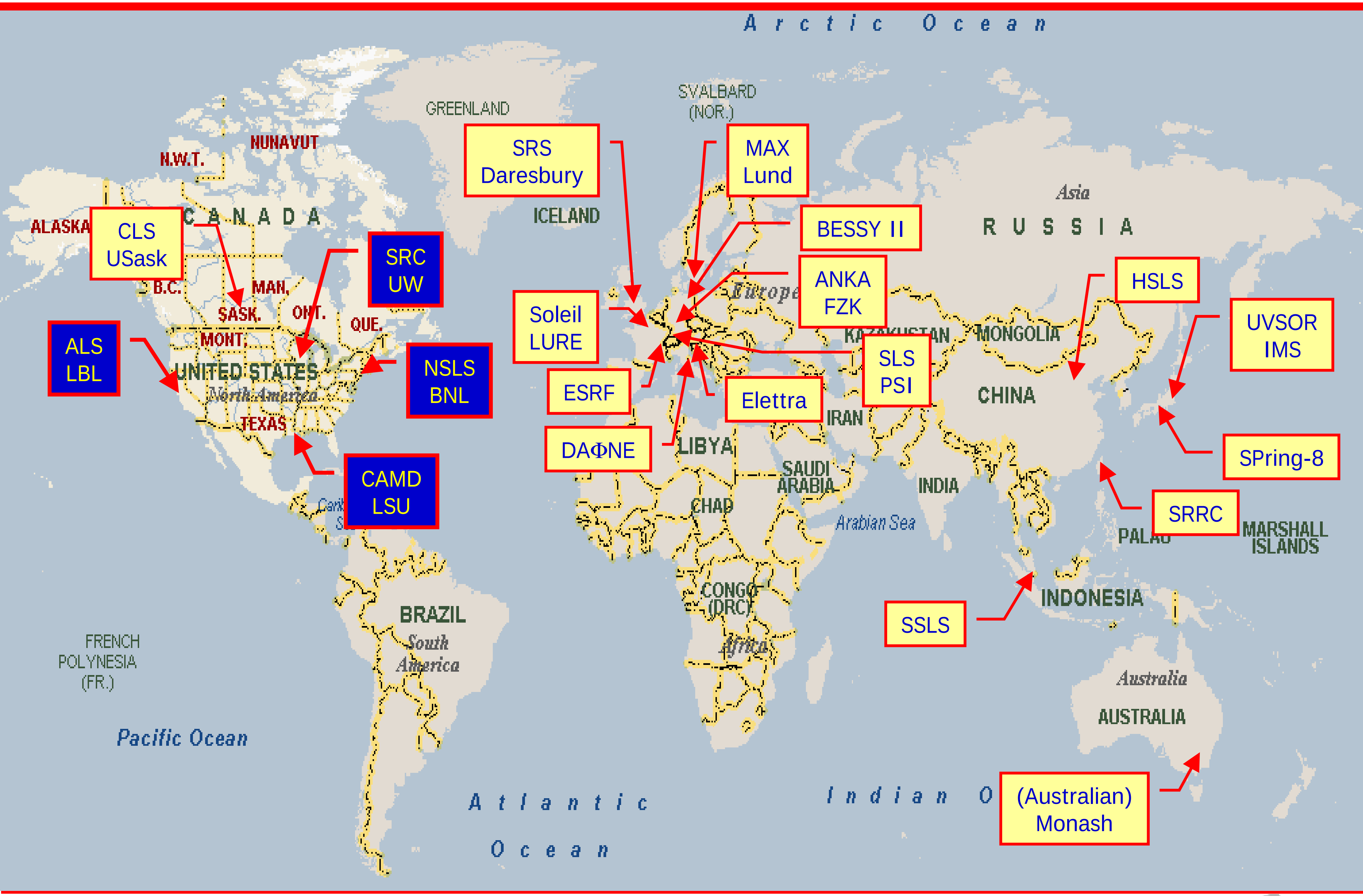
Very high (spectral) resolution (requires small collimating aperture)

$r = f\,(2\delta\nu/\nu)^{1/2} = 2$ mm

for $f = 20$ cm, $\delta\nu = 0.001$ and $\nu = 20\ \mathrm{cm}^{-1}$



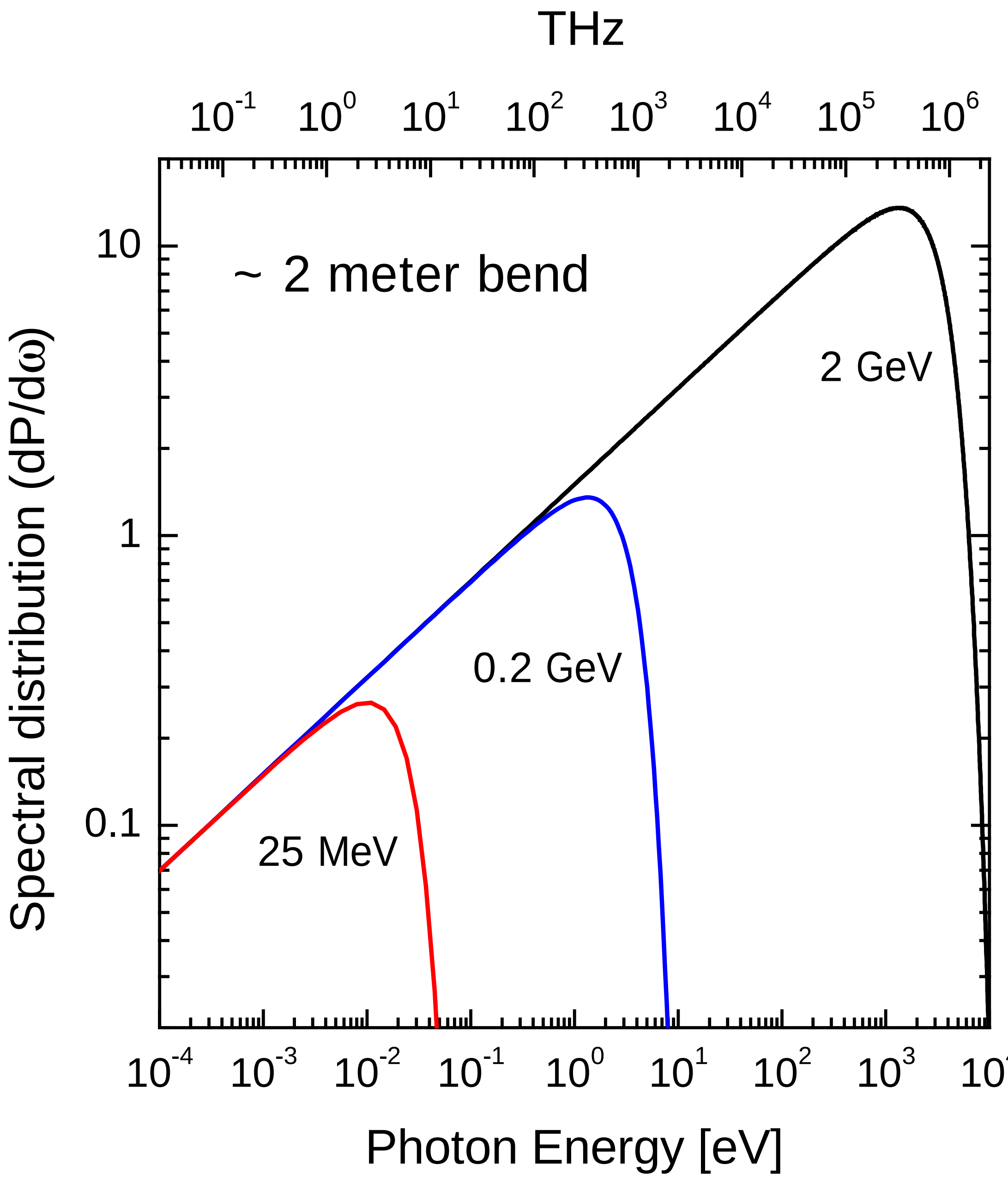
# Worldwide Synchrotron Radiation Facilities for Infrared



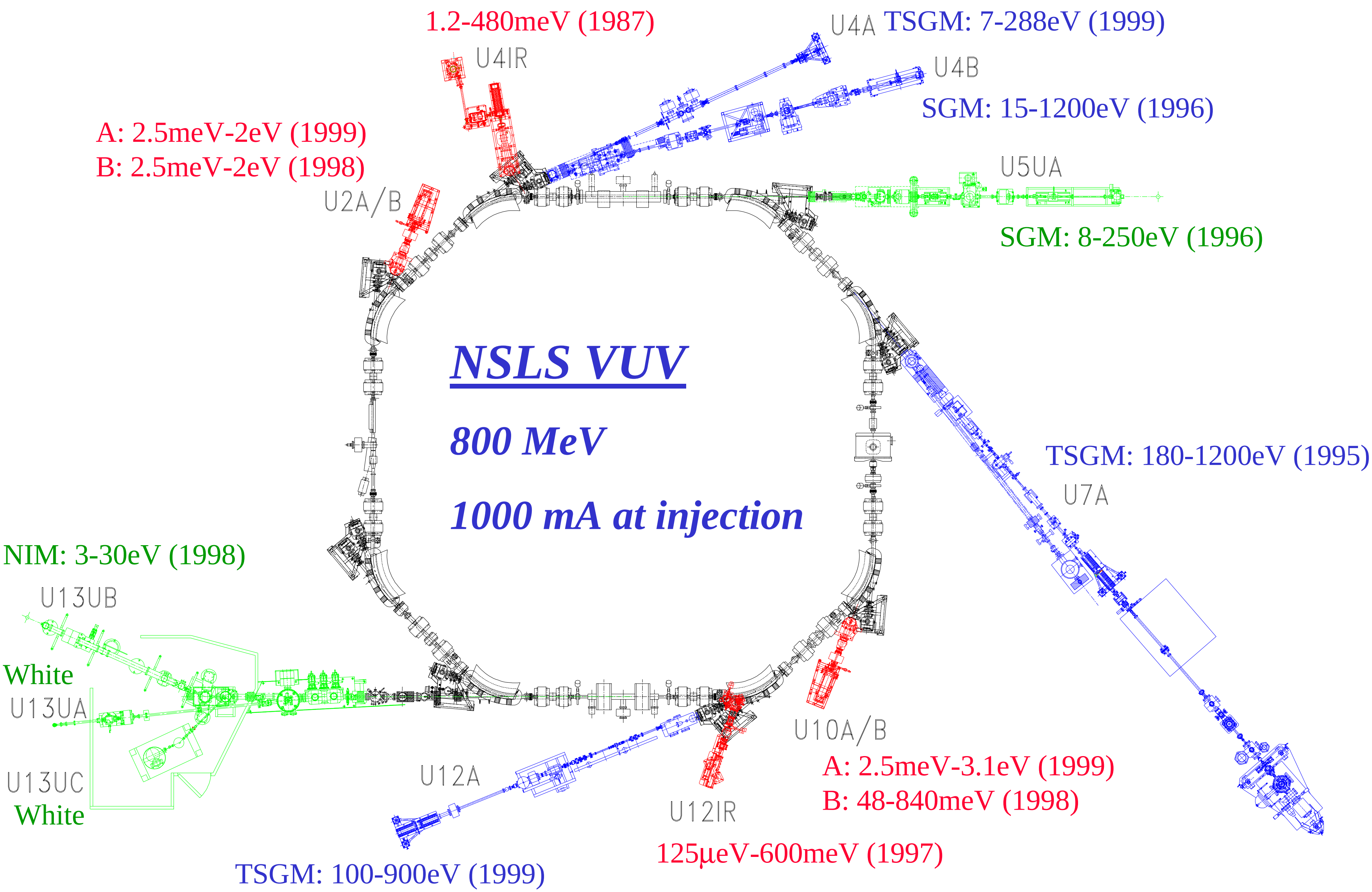
# Synchrotron Infrared Brightness

If electron energy is sufficiently high (> 100 MeV) then IR brightness depends only on:

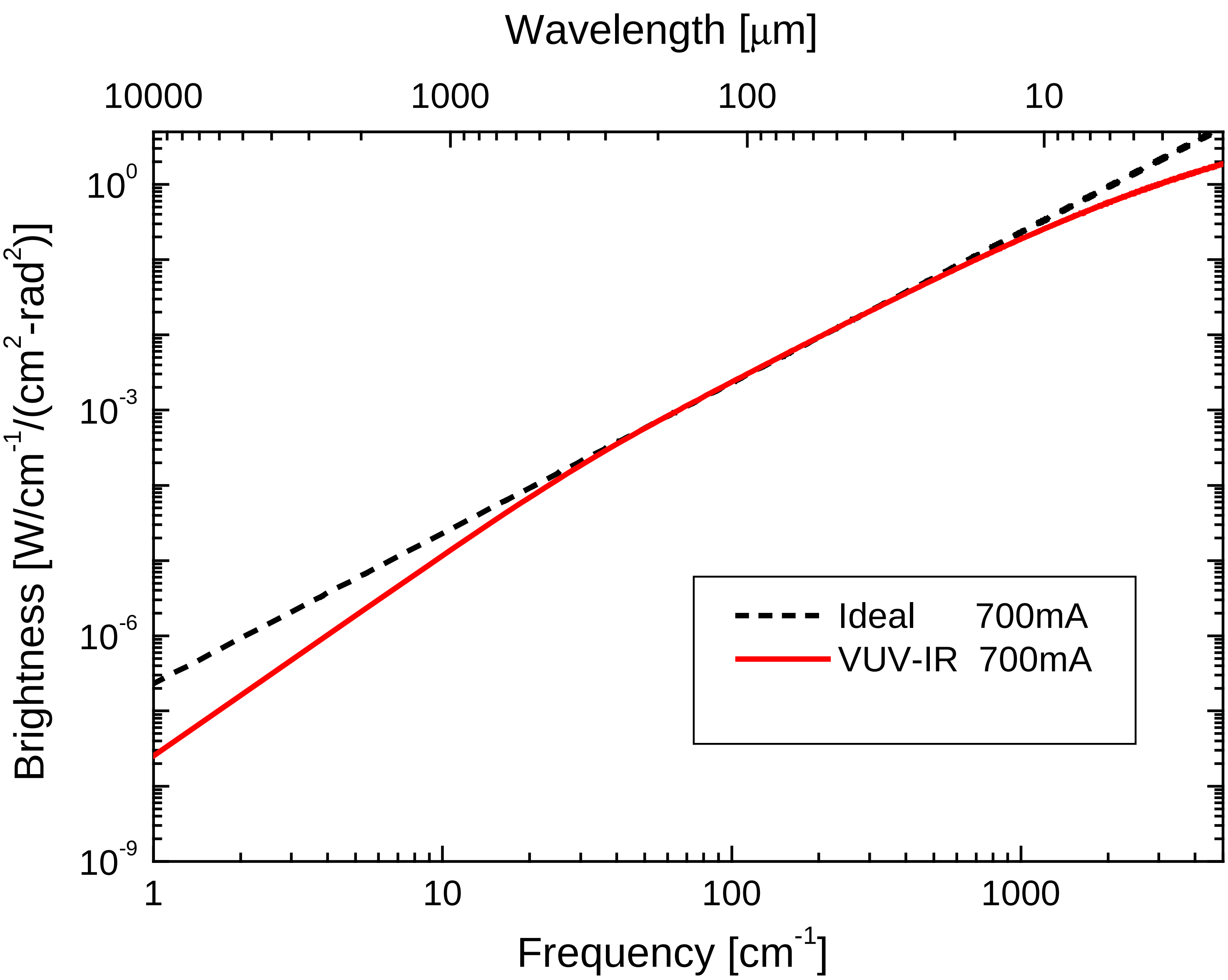
- beam current
- source size/emittance
- extraction aperture



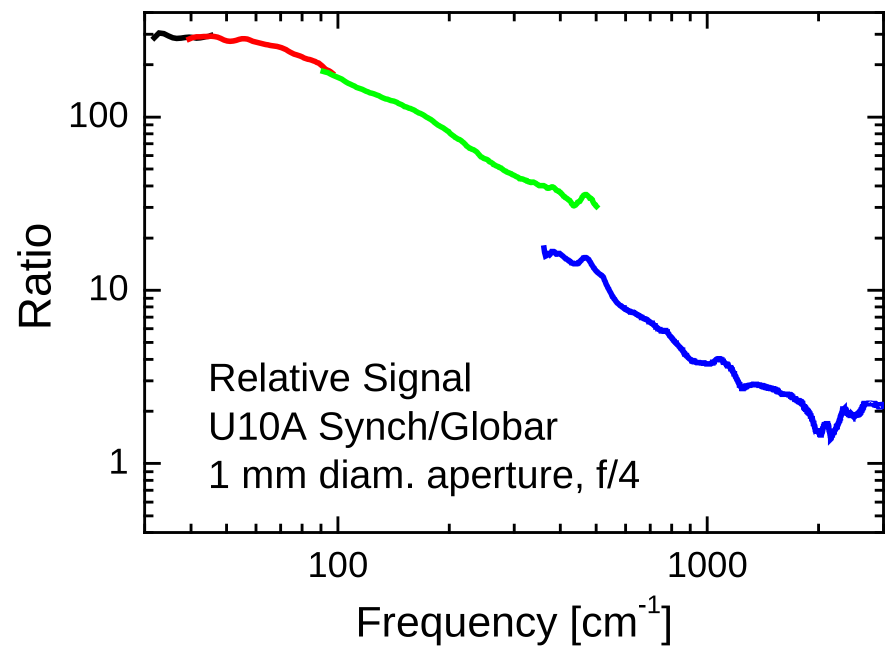
# Recently Upgraded VUV/IR Beamlines

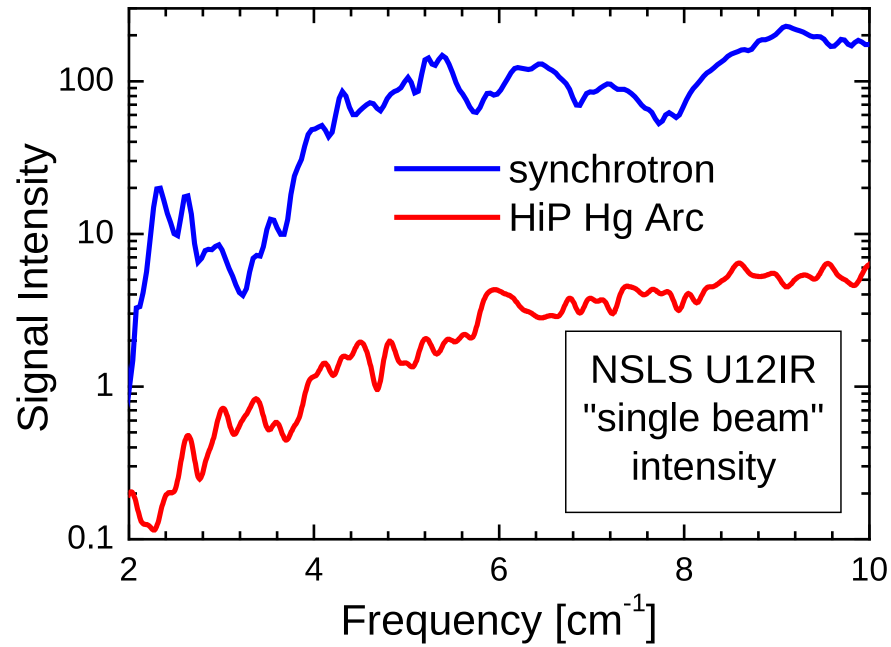


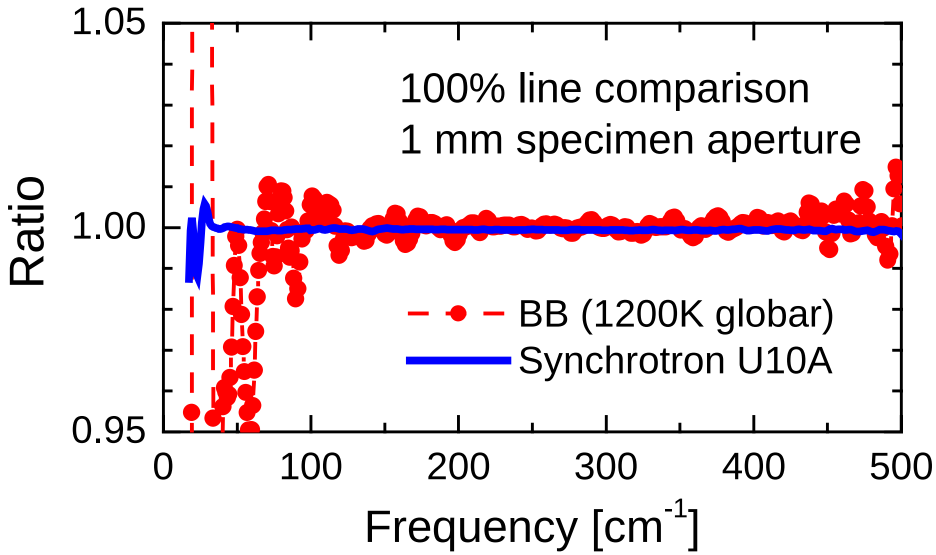
# IR Performance of VUV Ring: 90x90mr Extraction

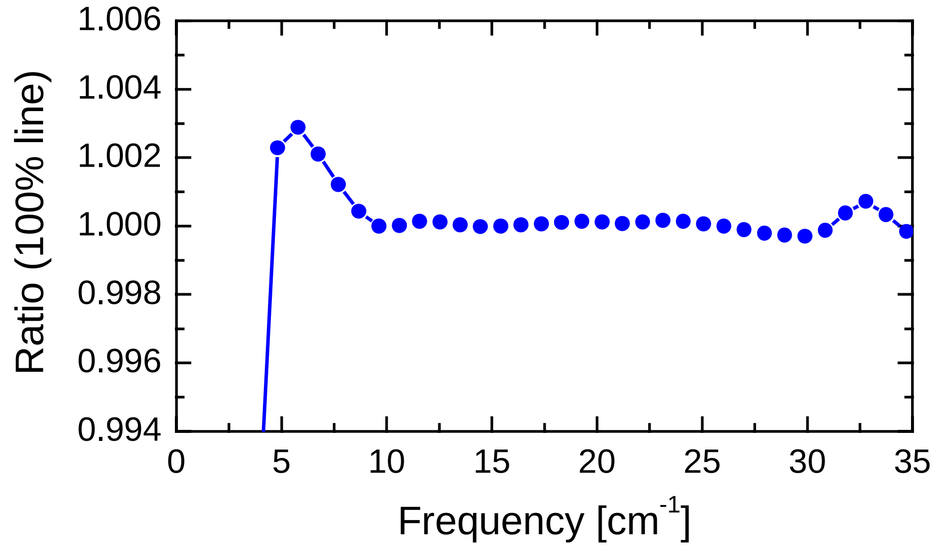


# Infrared Performance: NSLS VUV Ring



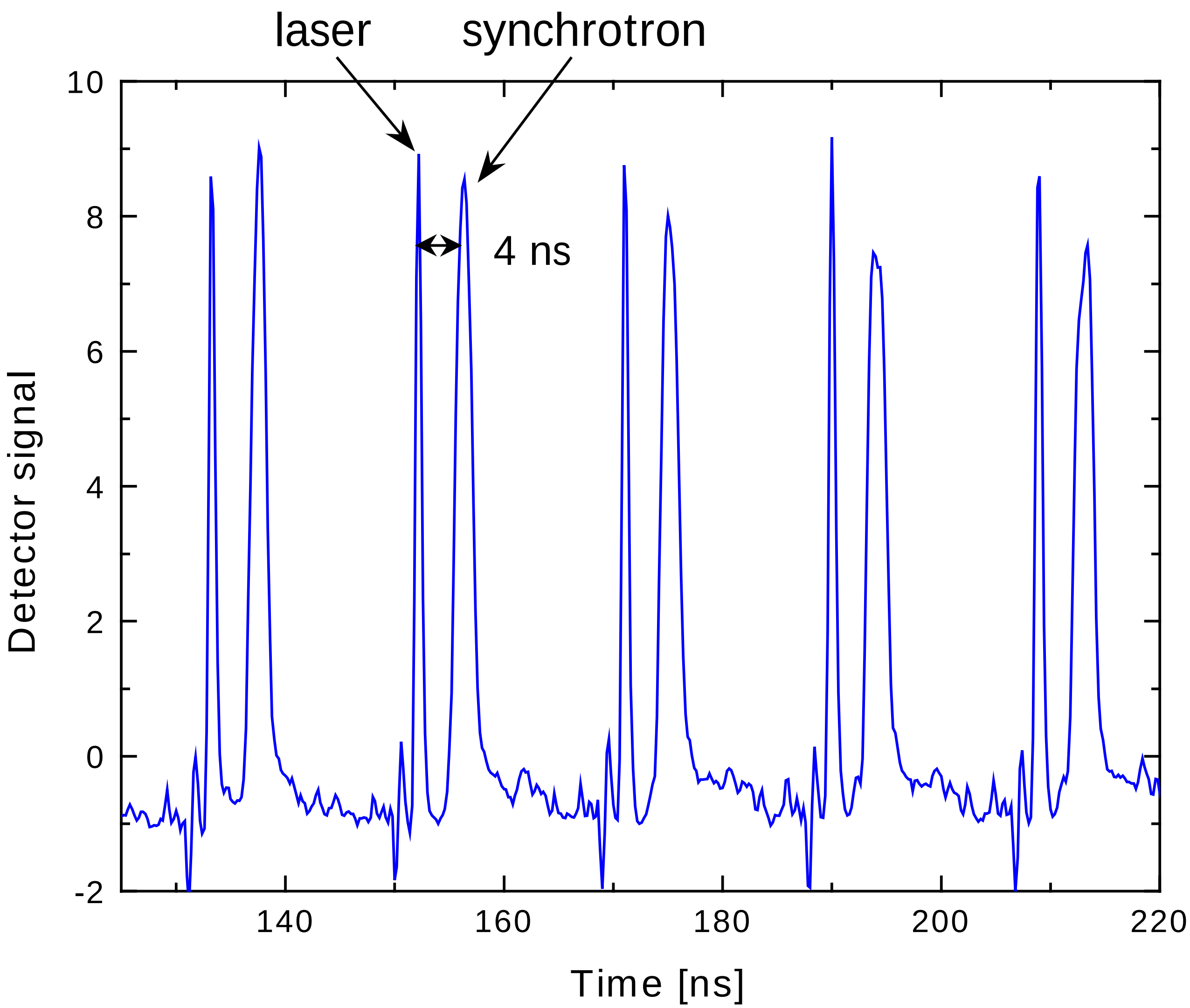



# Pulses for Time-Resolved Spectroscopy

- Synchronized M-L laser (<10 ps pulses) & VUV ring pulses (down to 300 ps).
- Need shorter synchrotron pulses (down to 100 fs, but <u>any</u> gain is useful)



# Existing IR Programs/Activities

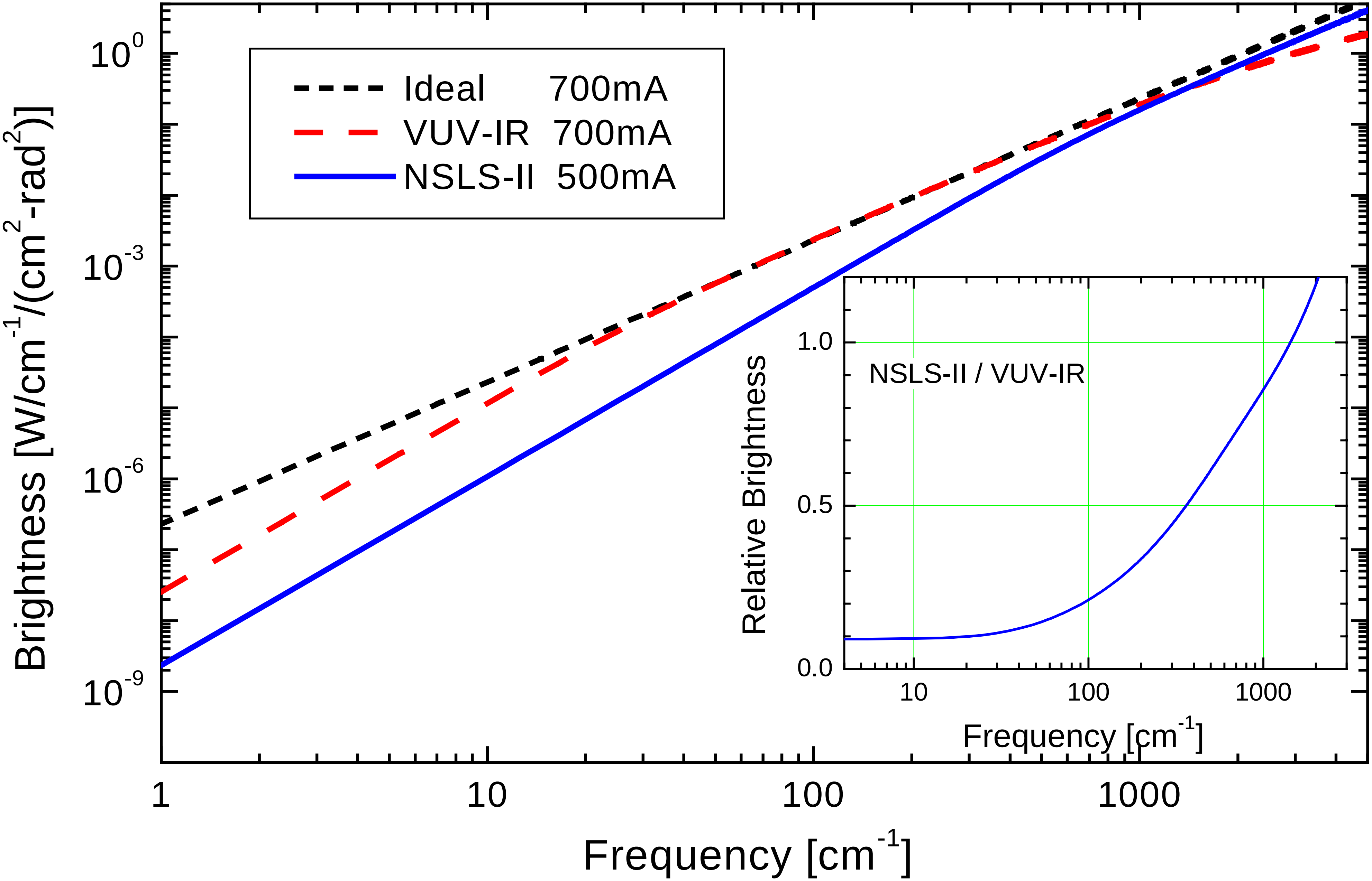
- Biological and Life Sciences
  - vibrational microscopy/imaging of proteins and cell structures
  - bone mineralization osteoporosis/osteoarthritis
  - chemistry of diseased tissues at the cellular level
- Environmental and Space Sciences
  - vibrational microspectroscopy of soils and interplanetary particles
- Corrosion and Catalysis
  - grazing incidence spectroscopy of molecular layers on metal surfaces
- Geosciences
  - spectroscopy and microscopy of molecular solids and minerals at extreme pressures and temperatures.
- Materials
  - infrared conductivity of complex metal oxides.
  - dynamics (time-resolved) in superconductors and nanomaterials.
  - spectroscopy of spins and magnetic resonances in ordered solids.

# Infrared Considerations for NSLS-II

- Existing NSLS & VUV/IR Ring
  - high current (high brightness), ~ 1 ns duration pulses
  - ~ <u>25 years old</u> (increasing maintenance for linac, booster, RF systems)
  - ring chamber and magnets remain reliable

- NSLS-II: New Ultra-Bright Storage Ring for X-rays
  - 500 ma (top-off)
  - new injector
  - 500 MHz
    - at least 10X shorter bunches
  - <u>*but*</u> large aperture ports could be problematic
    - estimate 20 mrad from geometric considerations.

# Infrared on the NSLS-II Main Ring?



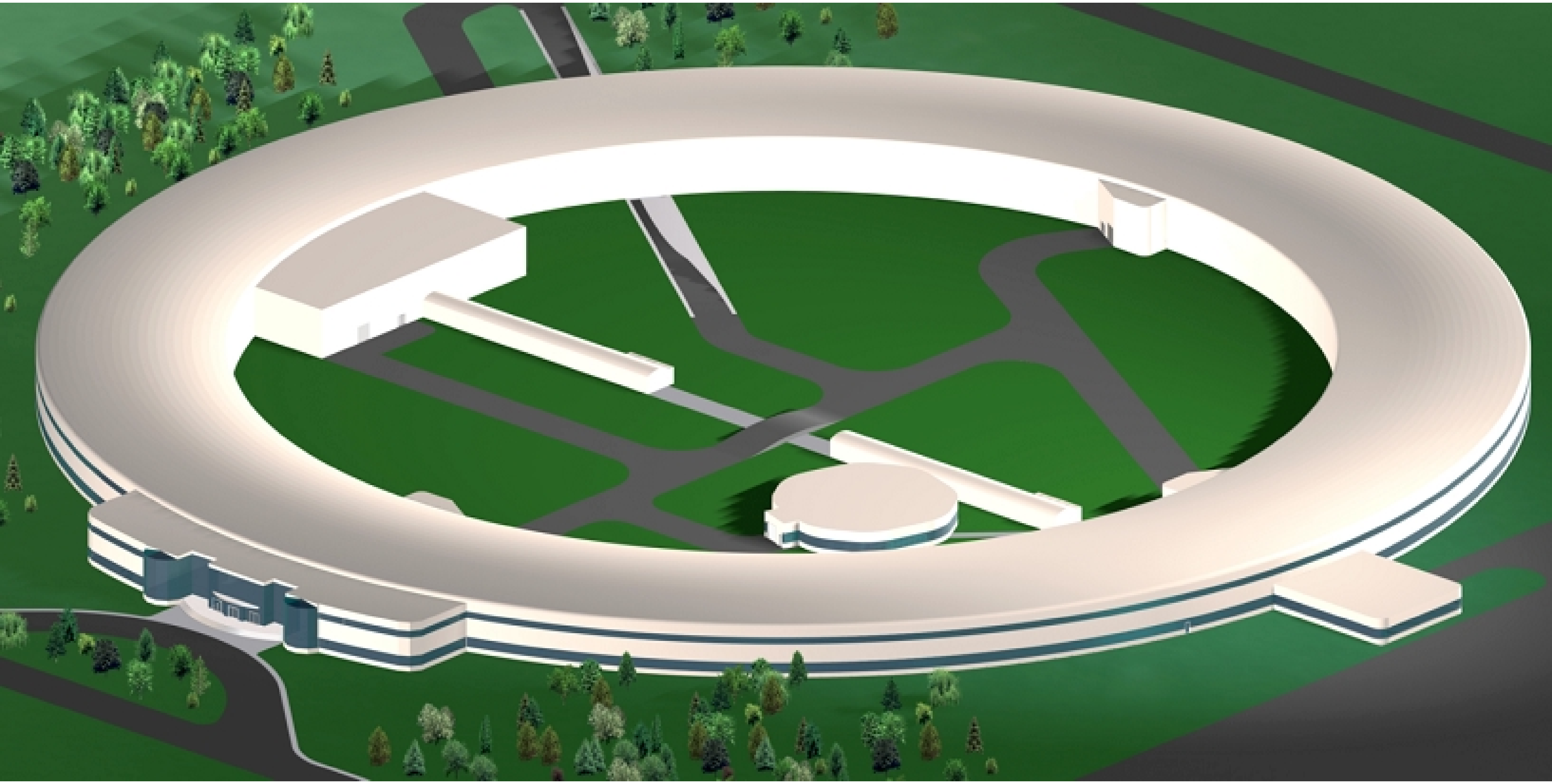
# Plan: Relocate VUV/IR to NSLS-II: Infrared Ring

- Maintain investment in ring chamber, magnets and beamline front-ends

- NSLS-II -> new injector (Linac)
  - Top-off injection for IR too
    - can tolerate modes with shorter lifetimes
      - brighter mid-IR beam
      - higher average current (1 A)
      - short bunch lattice

- New RF
  - 500 MHz to match NSLS-II systems
    - intrinsically shorter bunches (10s of picoseconds)
    - possible coherent mode?

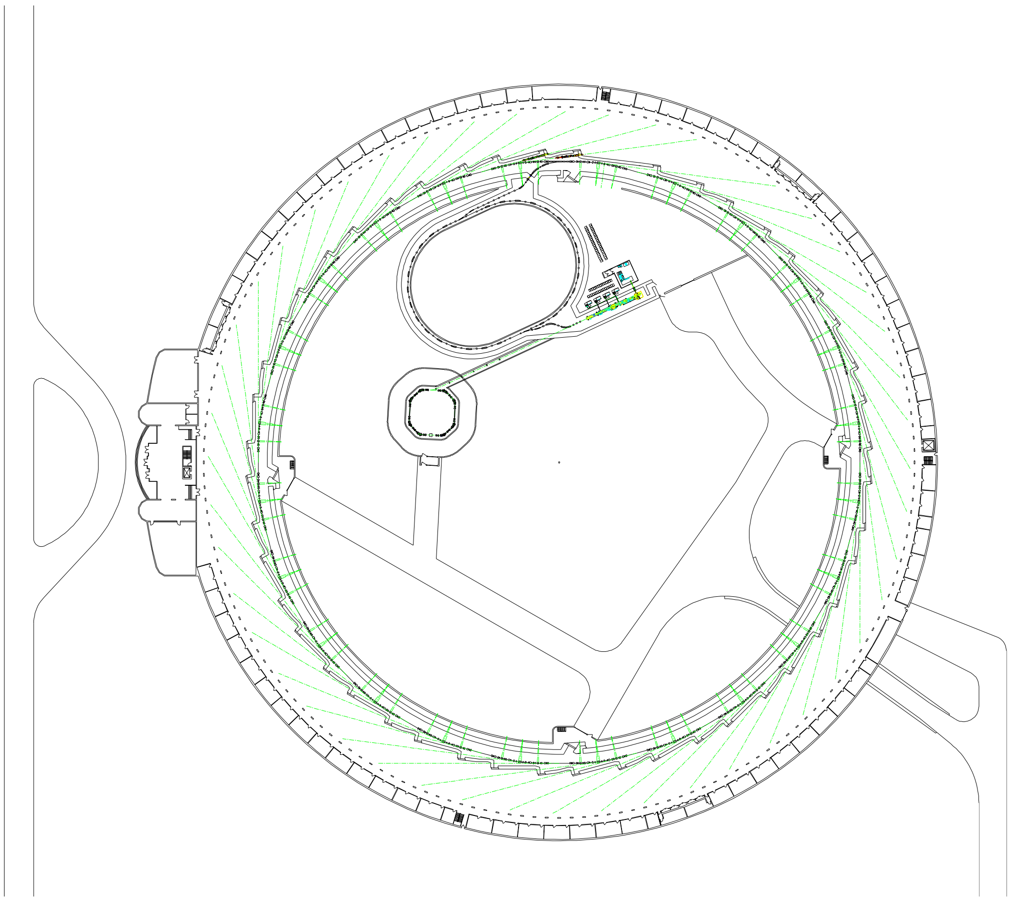
# The NSLS-II Project

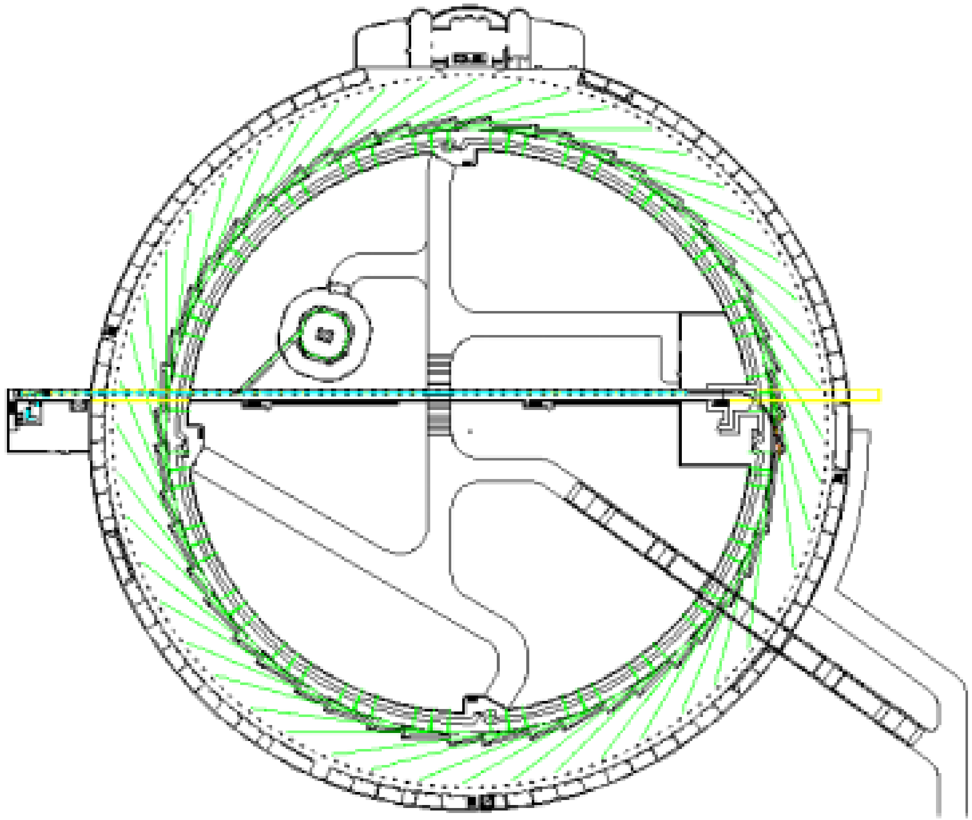


# NSLS-II Infrared Ring

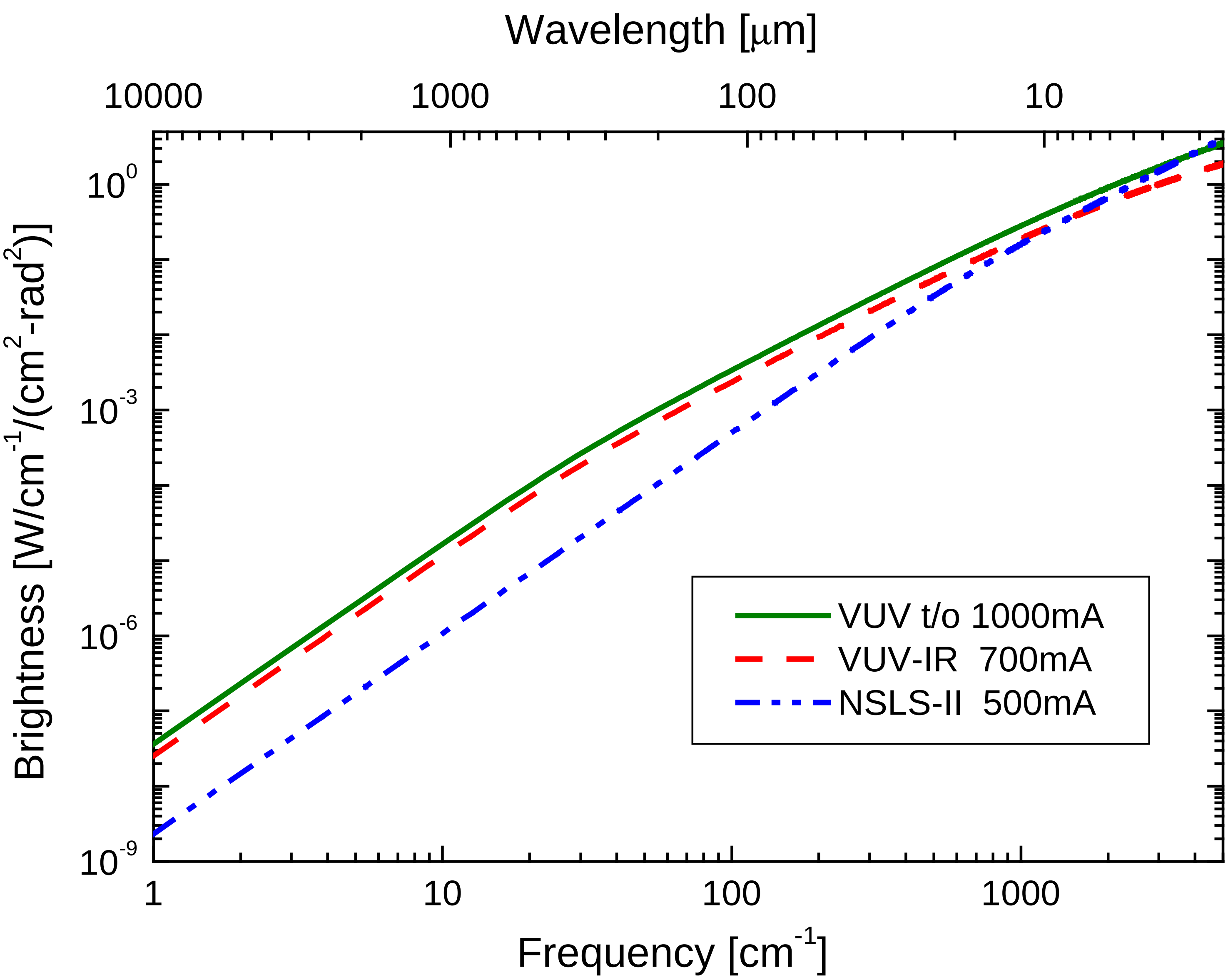
<u>Option 1:</u>
200 MeV linac + Booster
Inject IR ring at 200 MeV

<u>Option 2:</u>
3 GeV linac
Inject IR Ring at up to 800 MeV

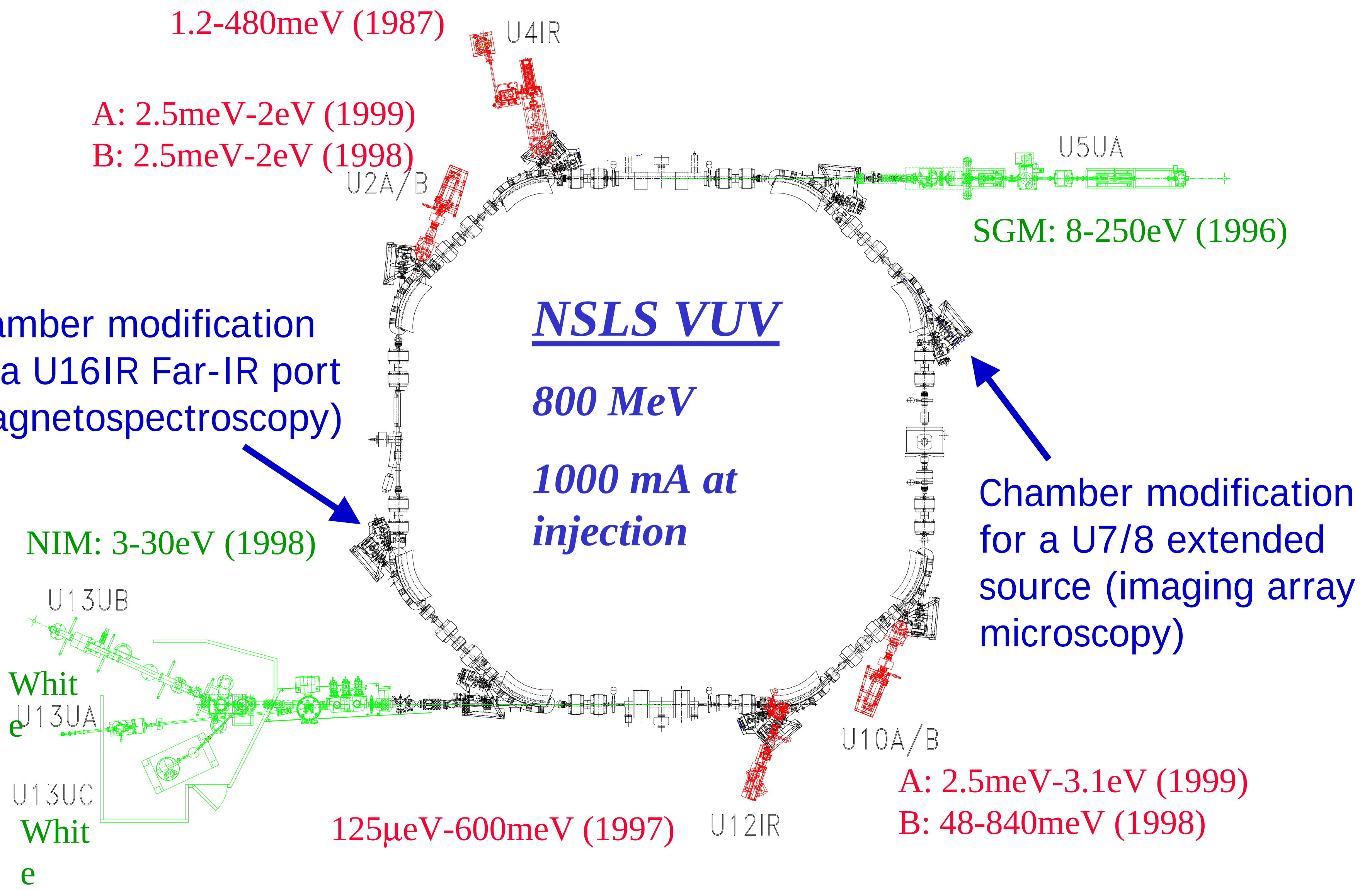




# Infrared Brightness Comparison



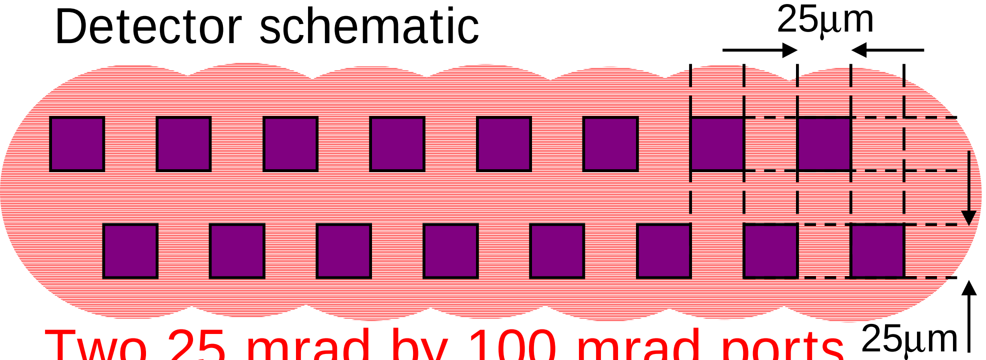
# Possible Infrared Beam Ports



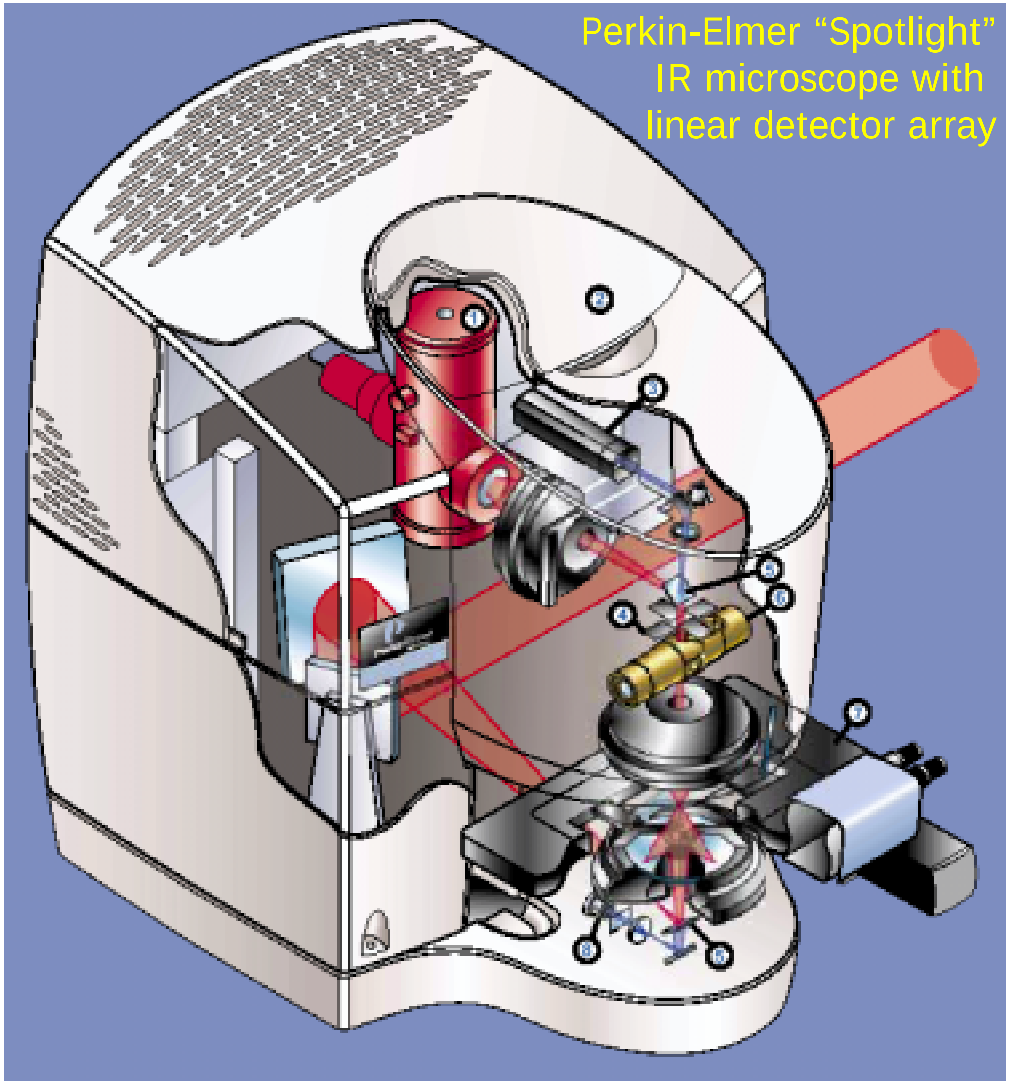
# Extended Source for Small Array FTIR Microspectrometer

- Rapid scan FTIR with 16 element array detector
- Full spectral range MCT

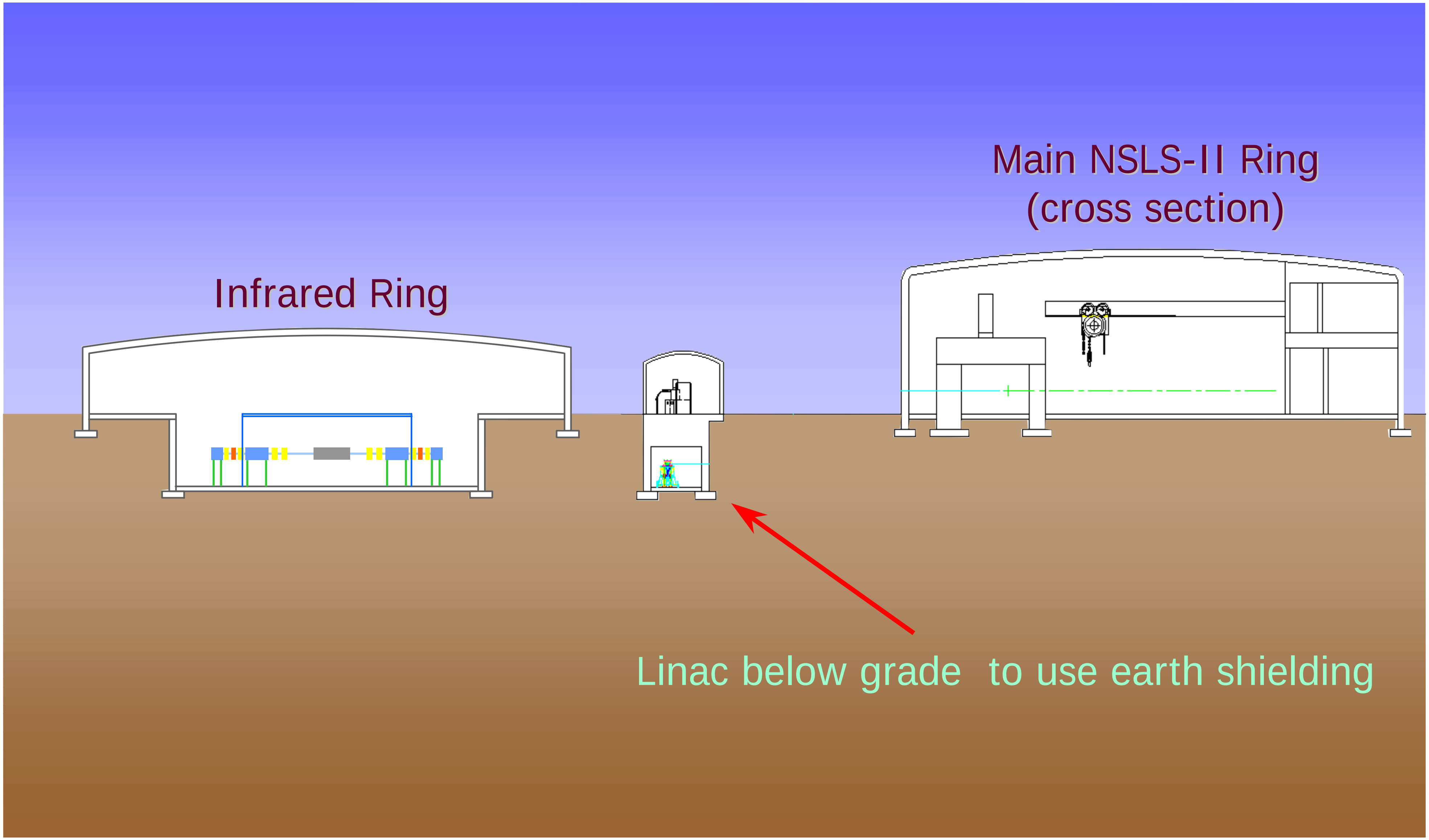
Detector schematic



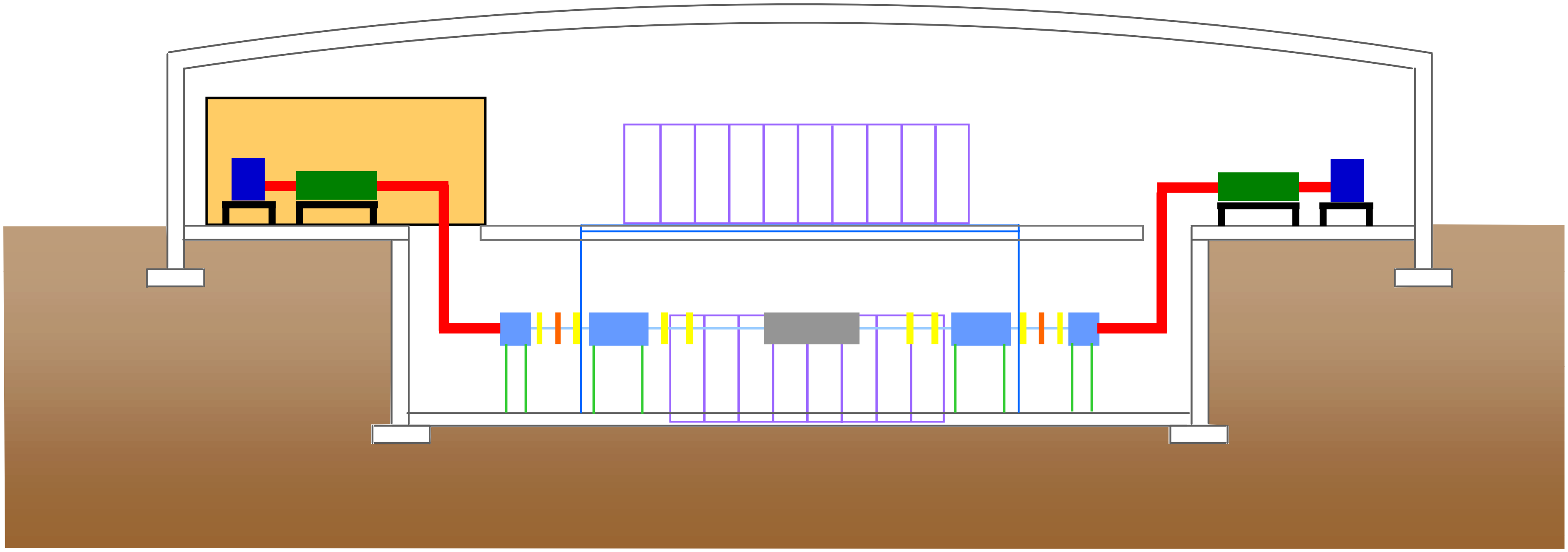

Two 25 mrad by 100 mrad ports



# Rough / Strawman Elevation Drawings



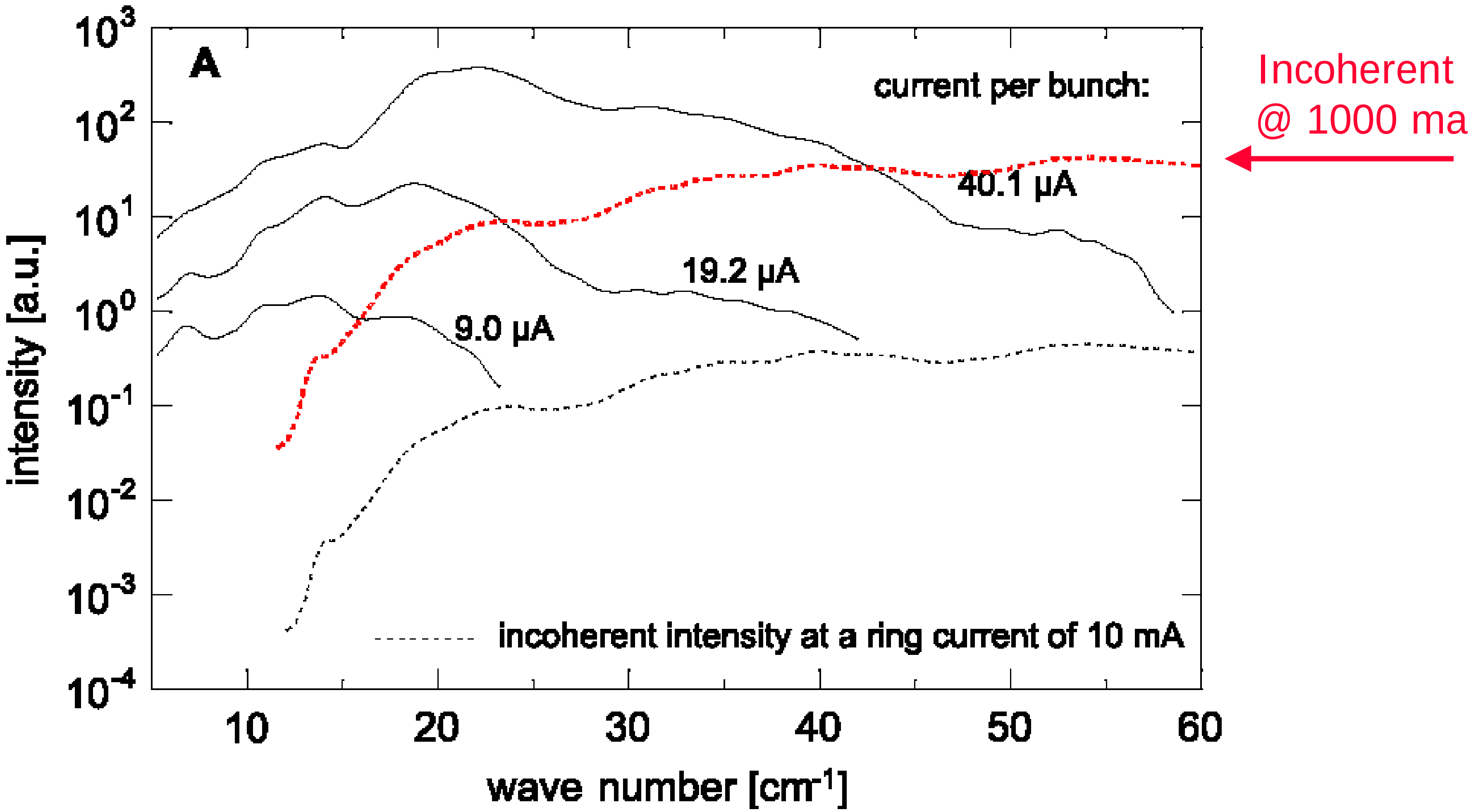
# Rough Infrared Ring and Beamline Strawman / Schematic



- Infrared beamlines extract light from ring (below grade)
- Endstations on upper level (stable concrete support)
- Most of ring covered (additional useful floor space, walkways)

# Other Possibilities: Coherent Emission

- Abo-Bakr et al demonstrate stable coherent emission from BESSY II (PRL March 2003)
- Berkeley Lab proposal for CIRCE (storage ring primarily for coherent far-IR)



# Summary & Questions

Current plans call for relocating NSLS VUV/IR Ring to NSLS-II

- Space for additional ports and beamline endstations
  - Let's make sure it's all stable!
    - beamline hutches for environment stability?
  - extended source based on 200 mrad horizontal (two U10 or U2 ports)? New Imaging Capability
- Top-off mode for higher current and higher brightness
  - how often?, how stable?
- 500 MHz RF
  - shorter bunches … modes for very short?
  - coherent emission?
- At least 200 MeV
  - adequate for IR and Visible, but may need more to avoid excessive topping-off
  - higher energy -> undulators could serve as tunable pump for time-resolved